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ABSTRACT

As a collaborative effort between Brown University (Rhode Island) and three secondary schools, an instructional hypermedia research project called ACCESS (American Culture in Context: Enrichment for Secondary Schools) has created a corpus for use at the high school level which contains a substantial amount of textual, pictorial, audio, and video materials. These materials are intended to supplement traditional courses in American history, literature, and American Studies. The goals have been to provide students with information and materials that will help integrate the three disciplines and give students a broader perspective on American culture and a structure that will encourage their active participation in the learning process. Students interact with the system through a mouse-driven interface and are able to take notes electronically as they use the system. Two studies have been conducted to identify educational and cognitive outcomes resulting from the use of hypermedia instructional environments, the basic cognitive mechanisms underlying the acquisition of expertise in non-rule-based but richly linked domains such as history and literature, and the basic principles that should underlie the construction of such a system. An underlying cognitive construct has been postulated, i.e., the conceptual neighborhood, which consists of a cluster of related facts and/or instances and the relationships between them. Systematic documentation of the relationship between students' interactions with a large hypermedia corpus and their conceptual representations derived from it has begun to show that hypermedia is an effective tool for conveying complex interrelationships between ideas for the vast majority of students. (10 references) (BBM)

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LEARNING FROM HYPERMEDIA:

MAKING SENSE OF A MULTIPLY-LINKED DATABASE

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Paper presented at the Annual Conference of the American Educational Research Association (Chicago, IL, April 3-7, 1991).

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Learning from Hypermedia: Making Sense of a Multiply-Linked Database[1]

Kathryn T. Spoehr and Amy Shapiro, Brown University

In recent years computer-based hypermedia has begun to attract widespread attention as an innovative instructional medium (e.g., Beeman et al., 1987; Hammond, 1989; Marchionini, 1989). Hypermedia allows the user to explore a body of knowledge that is organized by multiple connections between pieces of information and others related to them. In hypermedia the basic units of information comprising the overall *corpus* may be static text, video, computer graphics, animation, sound or any other technology that can be computer controlled. By convention these basic units are referred to as *nodes*, while the connections between them are called *links*. Although different hypermedia interfaces support different types of user interactions, the allure of hypermedia for instruction lies in its ability to actively engage the student user in the acquisition of information, its ability to support multiple instructional uses, such as tutoring and research, and its inherent ability to support different learning styles. Rand Spiro and his colleagues (Spiro et al., 1987) have also noted that hypermedia instruction naturally promotes both the acquisition of multiple representations that characterize expert-level understanding of complex, non-rule-governed domains, and also the use of such multiple representations in problem solving within the domain.

Our purpose in this paper is twofold. First we will present an overview of an instructional hypermedia research project called "ACCESS," or more specifically "American Culture in Context: Enrichment for Secondary Schools." The second purpose is to present some data showing why hypermedia is a particularly effective instructional technology for teaching history and literature, the two subjects with which ACCESS has been primarily concerned.

The ACCESS Project is a collaborative effort between Brown University and three secondary schools and has been underway for nearly three years. The software development part of ACCESS has been aimed at creating a substantial hypermedia corpus for use in high school level. It has been constructed use HyperCard on Macintosh SE computers primarily by high school teachers, with Brown University staff providing software and other technical support. The corpus now contains a substantial amount of textual, pictorial, audio, and video materials intended to supplement traditional materials and teaching methods for courses in American history, literature, and American Studies. Our goals have been to provide students with 1) contextual information that will deepen and broaden their understanding of the two disciplines separately, 2) material that will help integrate the two disciplines to give students a broader perspective on American culture, and 3) a structure that will encourage active student participation in the learning process. The current corpus contains 4,741 cards (screen images), and occupies 24.1 MB of hard disk storage. In addition it makes use of material on two commercially available video disks.

The system supports a variety of browsing and information retrieval strategies through a mouse-driven interface, and allows students to take notes electronically as they as the system. We have nearly 400 students across our three schools using ACCESS on a regular basis this school year.

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IR 015037

Development and Deployment of the ACCESS Corpus

Sites: 1988-1991: Lincoln School, Providence, RI (Corpus development and use)
1989-1991: Hope High School, Providence, RI (Corpus development and use)
1990-1991: Sheldon High School, Eugene, OR (Corpus use only)

Nearly 400 students are using the ACCESS corpus during the 1990-91 school year across the three sites.

System Requirements: Macintosh Plus, SE, MAC II, with hard drive
HyperCard 1.2 or higher
National Gallery of Art and *Martin Luther King* video disks.

Authoring: Basic stack design and scripting done by Brown University staff on the basis of teachers' specifications.

All material is being selected, organized, and entered by teachers.

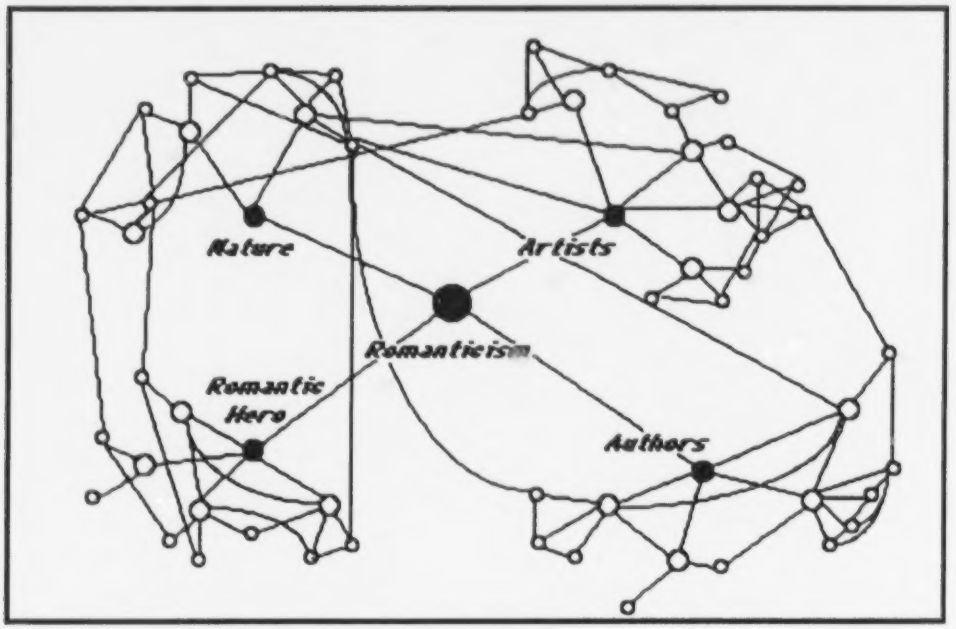
Concomitant with the software development effort we have also conducted a program of basic research focussed on three issues: 1) What educational and cognitive outcomes result from using hypermedia instructional environments? 2) what basic cognitive mechanisms underlie the acquisition of expertise in non-rule-based, but richly linked domains such as history and literature? and 3) What basic principles should underlie the construction of hypermedia instructional systems?

Our investigations of the first two issues, namely expertise and student learning, have led us to postulate an underlying cognitive construct, the *conceptual neighborhood*, which seems crucial to the knowledge representation in these domains. A conceptual neighborhood may be roughly defined as a cluster of related facts and/or instances, plus the relationships between them. The psychological literature on the nature of conceptual representation of natural categories (e.g., Rosch, 1975) contains many examples of similar structures where a category such as birds may be defined extensively in terms of specific exemplars such as robin, bluejay, turkey, etc., and the exemplars themselves may be thought of as being connected by a series of labelled links denoting the nature of the relationships between them. Many investigators, including ourselves, have found that experts have both more and larger conceptual neighborhoods (Dawson, Zeitz, and Wright, 1989), and that their conceptual neighborhoods have more internal coherence within subparts, and more differentiation between subparts (Chi and Koeske, 1983).

In education the concepts are often more abstract and general as, for example, the concept of "romanticism." Nevertheless many of the important facets and implications of such concepts can be instantiated in a hypermedia corpus by a collection of nodes of information and the links between them. For our purposes we have taken the particular collection of nodes and links associated with a concept as defining its *conceptual neighborhood*. Clearly the number of patterns of links between a given set of nodes is potentially quite large, each one defining a different *conceptual neighborhood structure*. Conceptual neighborhoods for large, abstract concepts typically have structures with multiple sub-neighborhoods within which there are many

links, and between which there are fewer links. Also some nodes are more tightly bound to a given neighborhood than are others by virtue of having more connections to other nodes in that neighborhood. The figure below shows a part of the conceptual neighborhood structure for the concept of "romanticism" taken from the ACCESS corpus, and illustrates the phenomena of sub-neighborhoods and binding.

Conceptual Network Structure



Although many conceptual neighborhood structures might support browsing and simple information storage and retrieval, a much smaller set of them are likely to be effective in teaching students the important attributes and relationships for an abstract concept. In fact, our teachers instinctively settled on a dominant structural type in setting up the ACCESS corpus because they wished both to maximize the likelihood that students were able to extract major conceptual frameworks from the corpus, and because they wished to reduce the chances of students getting lost in the corpus. The solution they adopted was to superimpose a roughly hierarchical overview structure on the naturally occurring pattern of links between nodes in the corpus. The hierarchical nodes for the romanticism neighborhood are shown as heavy black circles in the figure. Such hierarchicalness is the logical result of a locally coherent and globally differentiated conceptual structure which, as we mentioned earlier, is the characteristic of expert-level representation (Chi, Hutchinson, & Robin, 1989). Notice also that it is often the case that any single node may be part of several conceptual neighborhoods depending upon which hierarchical overview route is taken to reach that node.

Let us now turn to the second purpose of this paper, which is to present some evidence that suggests why hypermedia is a particularly effective instructional technology for subjects such as history and literature. Our tentative hypothesis is that because expert-level understanding in these subjects is well-described by a conceptual neighborhood analysis, and because the goal of the educational process is for students to acquire an effective conceptual neighborhoods, hypermedia inherently carries the advantage of visibly instantiating relevant neighborhoods and allowing students to use and interact with them. Although our evidence to date is only

correlational, we would like to present some of the data that has led our thinking in this direction.

There are two types of data that bear on whether a student is using a hypermedia corpus to build up her/his own conceptual structure. One is the record of a student's interaction with the system. Since ACCESS permits us to collect records of each student's sessions we are in a position to tell whether students are making use of the neighborhood structure in the corpus. To examine what type of conceptual structure students construct on the basis of this experience, we also examined written work based on their corpus interactions. We began by analyzing the student usage trails for all sessions during which they were researching a two-page essay comparing Thomas Jefferson and Andrew Jackson. This was the first major written assignment given in one of our history classes based on the corpus, and was given quite early in the school year. Thus the usage patterns are more likely to reflect "natural tendencies" than to reflect the build-up of traversal habits acquired from extensive use of the corpus.

The first column (marked "Early in School Year) in Table 1 summarizes the student's behavior during the monitored sessions. In addition to the total number of cards viewed, we tabulated the percentage of cards viewed that were overviews, the percentage of screen transitions which were linear (from one card to the next in an electronic page-turning mode), the percentage of pop-up moves in which the student moved from one level of the neighborhood hierarchy to the next higher one (an index of the extent to which the student was making use of the expert-level organization provided in the corpus), the percentage of non-linear moves in which a student followed a link to some other part of the corpus, the percentage of all nodes at each level hierarchy in the relevant part of the corpus visited by the student, and the percentage of all screens in multi-screen sequences that were viewed (to make sure that students were reading to the end of the sequences).

Although this data will become more meaningful when compared to that generated by the same students later in the school year, some generalizations can be made. The students viewed considerably more screens than necessary, and this number represented many, many repetitions of a much smaller set of relevant screens. The fact that only 24.4% of the viewed cards were overviews indicates that many students were able to isolate the relevant portions of the corpus and stay in those general neighborhoods. The preponderance of linear moves resulted from the fact that many were necessary in order to move across the many multi-card sequences in the corpus. Students were also highly reliable in viewing all of the material associated with a node once they got to that node.

Table 1
General Corpus Scanning Behavior

	Early in School Year	Late in School Year
Total Cards Seen	195.4	248.3
% Overview	24.4	15.2
% Linear Moves	62.6	49.9
% Non-linear Moves	19.1	21.7
% "Pop-up" Moves	13.9	28.5
% of Branches Visited (L1)	29.0	55.1
% of Branches Visited (L2)	30.8	53.1
% of Branches Visited (L3)	37.2	42.8
% of Branches Visited (L4)	—	11.2
% Cards Visited in Series	92.0	97.4

A finer-grained analysis of this data reveals interesting differences in traversal patterns between students who ended up with ostensibly different conceptual understandings of the material. As a very rough measure of how good a neighborhood structure a student acquired, we used her/his grade on the associated essay. Table 2 shows our set of traversal measures broken down for students who got A's, B's, and C's on that assignment. Although there are no consistent patterns across mastery levels for many of the measures, we observed a reliable pattern of the better students making fewer linear moves and making more use of the hierarchical structure (as evidence by the % of pop-up moves). The better students also reliably visited a greater percentage of nodes at the deeper levels (L2 and L3) of the structure, which is to be expected if they made relatively more hierarchy traversing moves. Since the evidence is correlational in nature we cannot tell whether making use of the conceptual structure in the hypermedia corpus caused students to produce a better understanding, or whether higher ability students (who end up with better conceptual structures) are more likely to notice and make use of such structures in the corpus.

Table 2
Corpus Scanning Behavior as a Function of Assignment Grade
(Early in School Year)

	Grade		
	A	B	C
Total Cards Seen	265.4	124.7	240.8
% Overview	29.8	23.4	21.0
% Linear Moves	56.2	60.7	69.8
% Non-linear Moves	19.4	19.6	18.8
% "Pop-up" Moves	18.8	13.6	10.2
% of Branches Visited (L1)	33.6	23.6	32.4
% of Branches Visited (L2)	32.8	25.4	17.0
% of Branches Visited (L3)	40.8	33.4	21.0
% Cards Visited in Series	90.6	94.4	91.6

By the end of a full year of ACCESS corpus use, most students had become relatively proficient users of most features of the system, and we were curious to know whether the corpus traversal patterns changed as a function of this experience. Of course a number of other things had changed about these students over the course of the year -- they were older, they had learned more American history and literature and, we hope, had acquired a better sense of how to conceptually organize material in these subjects. We conducted a second systematic analysis of the corpus use sessions during which students were researching a two page essay in which they were to use the concepts of "celebrity" and "fame" as focal points for a comparison of two well-known persons during the 1920's. The assignment, given in late March, gave the students considerably more leeway in what they would write about, and thus an added dimension to their use of the corpus was to scout out appropriate individuals to use in their essays. Because of this a much larger segment of the corpus was potentially relevant to their endeavor. The right-hand column of Table 1 (labelled "Late in School Year") shows the results of our analysis.

Table 1 shows that the students, as a group, have changed their traversal strategies. The fact that the number of cards seen is greater on this assignment than on the earlier one is indicative only of the fact that there was more potentially relevant material to be viewed for this assignment. Since there since more of the relevant material for this assignment was associated with a few major conceptual neighborhood nodes, the percentage of overviews seen is lower. However, the students are making fewer electronic page-turning (linear) transitions and, instead, are relying more on the links and the hierarchical traversal methods (pop-up

moves). They are also visiting a greater percentage of nodes lower in the conceptual structure (L2 and L3), and continue to be thorough in viewing all material at a node once it is reached.

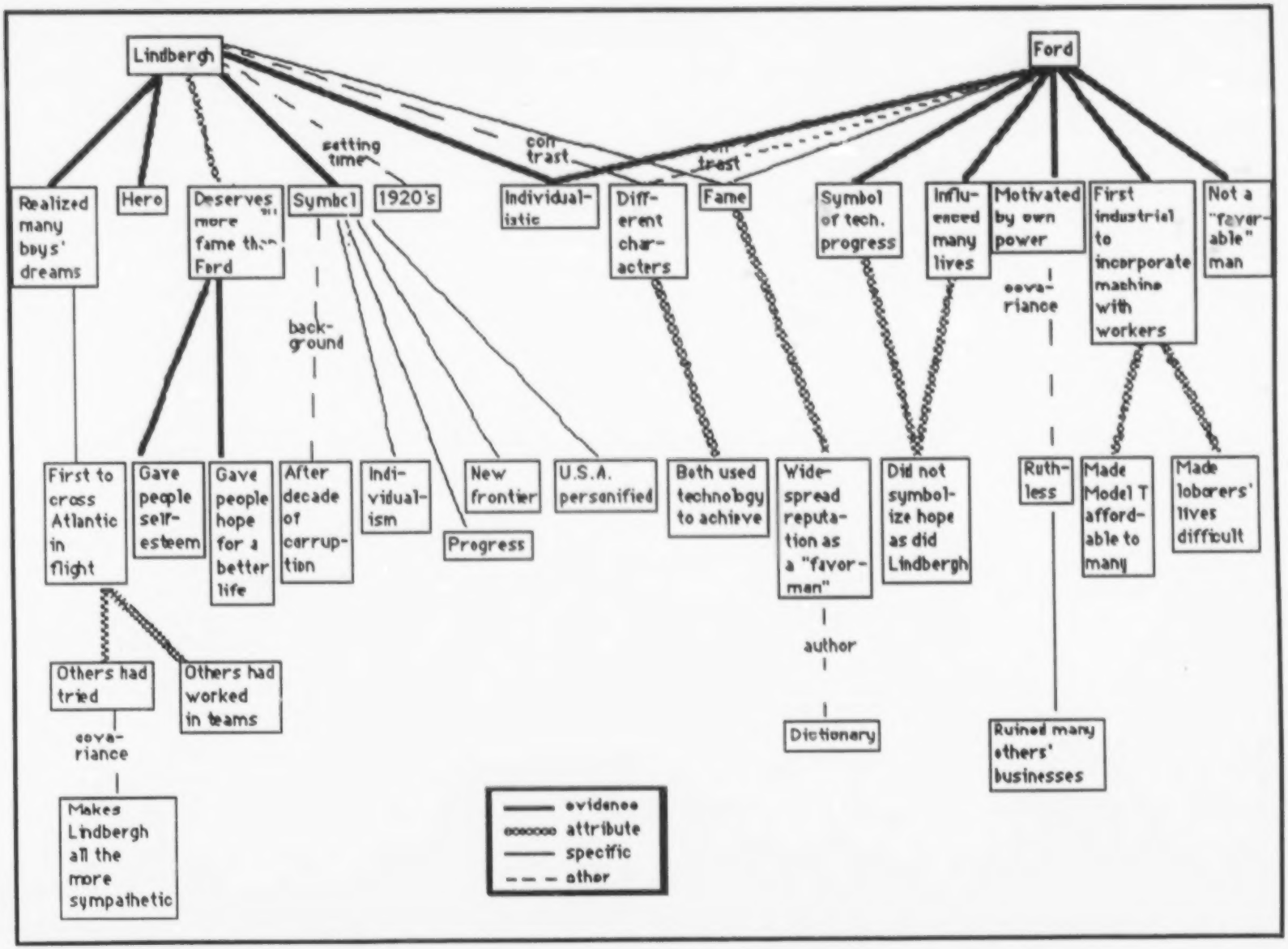
When we break down the corpus traversal data according to the adequacy of the student's resulting conceptual structure (as measured again by the grade on the associated written assignment), we again find some interesting individual differences. These data are given in Table 3. The better students tended to view fewer screens, which suggests that they not only repeated viewing the same screens less often, but they also focused their research more on a subset of the potentially relevant material. Interestingly enough all three ability groups were equally likely to make linear page-turning moves, use the links, and move up and down the hierarchy. We conclude from this that the lower ability students learned how to organize their thinking along the conceptual lines embodied in the overview structure of the corpus and to thereby make better use of that structure in locating information. A- and B-level students also showed a significant tendency to visit a smaller percentage of nodes at each level of the conceptual hierarchy than did C-level students, which reconfirms our impression that they were using the structure in the corpus to focus their attention on a reasonably small subset of the material. This difference is also reflected in the fact that students who had good conceptual structures viewed a greater percentage of the relevant material and a lesser percentage of irrelevant material.

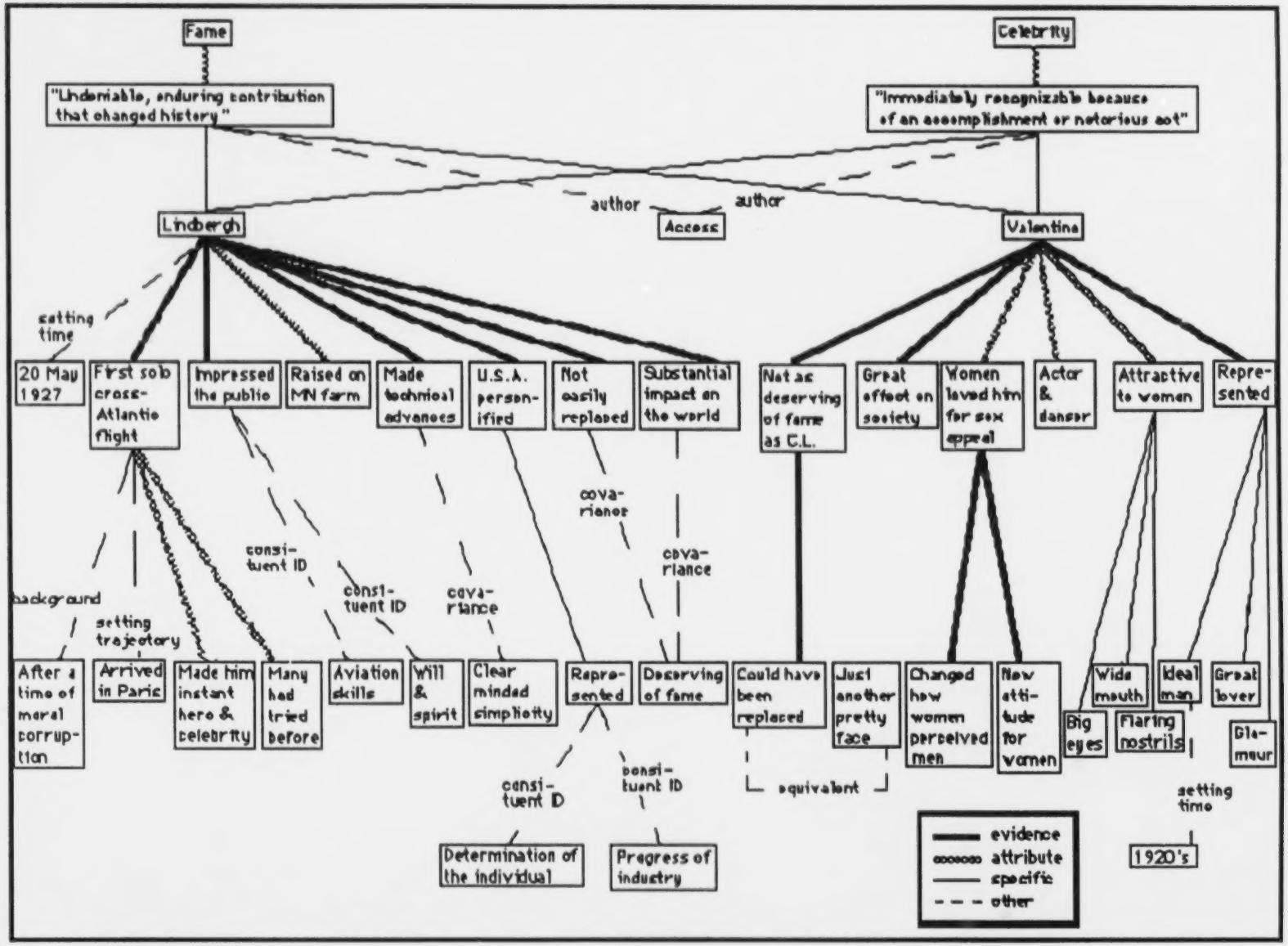
Table 3
Corpus Scanning Behavior as a Function of Assigned Grade
(Late in School Year)

	Grade		
	A	B	C
Total Cards Seen	165.0	199.7	447.5
% Overviews Viewed	17.0	15.2	14.0
% Linear Moves	50.4	48.6	51.0
% Non-linear Moves	23.2	23.1	18.0
% "Pop-up" Moves	28.2	28.2	30.5
% of Branches Visited (L1)	42.6	49.0	81.5
% of Branches Visited (L2)	44.8	44.1	82.5
% of Branches Visited (L3)	35.6	33.1	77.0
% of Branches Visited (L4)	10.0	1.9	17.0
% Cards Visited in Series	95.4	97.9	99.0
% of Relevant Cards Visited	93.8	86.7	75.0
% of Irrelevant Cards Visited	47.2	62.7	95.5

In order to examine the nature of the conceptual structures the students acquire from the corpus, we made a detailed analysis of the content and logical structure of each student's essay. The first figure below is a diagram of the structure of the major idea units for a student who did relatively poorly on the assignment. The various types of relationships between these idea units is depicted by the different types of lines. This student's organization was typical of those who did not do well on the assignment: the essay was organized into two main chunks according to the two individuals compared in the essay, and it placed great reliance on listing attributes of those individuals rather than on abstractions and evidence.

The second figure shows a similar analysis for a student who did somewhat better and got a B on the assignment. The essays of all of the A- and B-level students were organized as this one was -- in terms of the two abstract concepts of "fame" and "celebrity." Discussion of the individuals being compared was made entirely within this more abstract concept, and thus the essays showed much more use of evidence, abstractions, and extended chains of reasoning and much less use of simple attributes.


Lindbergh
Ford
Realized many boys' dreams
Hero
Deserves more fame than Ford
Symbol
1920's
Individualistic
Different characters
Fame
Symbol of tech. progress
Influenced many lives
Motivated by own power
First industrial to incorporate machine with workers
Not a "favorable" man
setting time
background
covariance
First to cross Atlantic in flight
Gave people self-esteem
Gave people hope for a better life
After decade of corruption
Individualism
New frontier
Progress
U.S.A. personified
Both used technology to achieve
Widespread reputation as a "favorman"
Did not symbolize hope as did Lindbergh
Ruthless
Made Model T affordable to many
Made laborers' lives difficult
Others had tried
Others had worked in teams
author
Dictionary
Ruined many others' businesses
Makes Lindbergh all the more sympathetic
evidence
attribute
specific
other


Fame
Celebrity
"Undeniable, enduring contribution that changed history"
"Immediately recognizable because of an accomplishment or notorious act"
author
author
Access
Lindbergh
Valentine
setting time
20 May 1927
First solo cross-Atlantic flight
Impressed the public
Raised on MN farm
Made technical advances
U.S.A. personified
Not easily replaced
Substantial impact on the world
Not as deserving of fame as C.L.
Great effect on society
Women loved him for sex appeal
Actor & dancer
Attractive to women
Represented
covariance
covariance
constituent ID
constituent ID
covariance
background
setting trajectory
After a time of moral corruption
Arrived in Paris
Made him instant hero & celebrity
Many had tried before
Aviation skills
Will & spirit
Clear minded simplicity
Represented
Deserving of fame
Could have been replaced
Just another pretty face
Changed how women perceived men
New attitude for women
Wide mouth
Ideal man
Great lover
Big eyes
Flaring nostrils
Glamour
equivalent
constituent ID
constituent ID
setting time
Determination of the individual
Progress of industry
1920's
evidence
attribute
specific
other

13

14

Table 4 summarizes the use of six types of idea relationships in the students' essays as a function of their grade on the assignment. It is evident that those students who had a better conceptual understanding of the ideas had more levels to their argumentative hierarchy, used more evidence, produced more specific instances of their examples, and used more facts and abstractions. The only category which the poorer students made more extensive use of was that of attribute listing, and this is to be expected in a person-based conceptual organization.

Table 4
Essay Structure Elements as a Function of Assigned Grade
(Late in School Year)

	Grade		
	A	B	C
Attributes	11.6	10.3	14.3
Levels	7.0	6.8	5.0
Evidence	11.4	10.7	4.7
Instances	5.2	5.2	1.7
Facts	29.8	26.0	27.7
Abstractions	15.6	13.2	7.3

How, then, is hypermedia use affecting the conceptual understanding of students who use it? Although all students seem eventually to come to value and use the conceptual structures built into the ACCESS corpus as information retrieval and browsing aids, not all of the students are equally able to internalize the important relationships. Those students whose corpus traversal patterns seem to be swamped by irrelevant paths also show understandings that are burdened by surface information, such as concrete attributes, which are often marginally important and occasionally unnecessary. These students thus come out with a less powerful and well-organized conceptual neighborhood structure.

By way of summary, the ACCESS Project has begun to show that hypermedia is an effective tool for conveying complex inter-relationships between ideas for the vast majority of students. Through our use of a large hypermedia corpus in classrooms we have been able to systematically document the relationship between students' interactions with such a corpus and their conceptual representations derived from it. It appears that the ways in which a student goes about finding material in a corpus affects both the content and structure of what they learn from it. The task for the ACCESS Project, and indeed for all instructional hypermedia systems is to make the corpus structures powerful enough to effectively affect *all* students.

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